PATENT SPECIFICATION

767,996

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International Classification :—B64f. G08c.

COMPLETE SPECIFICATION.

Supporting Model Aircraft or the like in a Wind Tunnel.

We, SIR W. G. ARMSTRONG WHITWORTH AIRCRAFT LIMITED, a British Company, of Baginton, near Coventry, Warwickshire, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement :—

This invention relates to the supporting of an aircraft model or the like in a wind tunnel so that its aero-dynamic characteristics may be analysed, and the invention is particularly concerned with a support by which the angles of incidence, roll and yaw of the model can be remotely controlled.

It is important when testing such a model in a wind tunnel containing dry air that the tunnel should not have to be opened for adjustment of position of the model, and for this reason the attitude of the model should be remotely controlled.

It is also important that the model, in any adjusted position, should be in a region of the tunnel which is free from air disturbances such as may be caused by small irregularities of the tunnel walls—particularly when the model is being tested with air travelling at supersonic speeds, as, in these conditions, shock waves can be formed within the tunnel.

One object of the invention is to provide an improved support by which the angles of incidence, roll and yaw can be remotely controlled, and by which the model can be maintained within a region of the tunnel which is free from disturbances.

A further object is to provide a support by which, when the attitude of the model is to be varied a given point of the model can be maintained in a predetermined position.

The invention involves the combination with an aircraft model or the like, of two relatively movable struts which extend into the wind tunnel and are arranged to be respectively moved, by means external of the wind tunnel, in a direction at right-angles to the wind tunnel axis, either in unison or independently, and also in unison along the wind tunnel, the struts supporting the model through the intermediary of means for rotating the model about its axis.

The invention also involves the combination with an aircraft model or the like, of two struts which are relatively-movable by respective drive means in a direction at right-angles to the wind tunnel axis, the struts being movable in unison along the wind tunnel axis by a further drive means, each of the drive means being controlled by a remote control in which the respective movements of the struts are integrated to maintain a selected point of the model in a selected position irrespective of any change of attitude of the model, the struts supporting the model through the intermediary of a means for rotating the model about its axis.

In the accompanying drawings:—

Figure 1 is a diagrammatic section through a wind tunnel showing a model-support according to the invention;

Figure 2 is a diagrammatic perspective view of the model-support ;

Figure 3 is a schematic diagram of the electrical circuits of the model-support and its control ;

Figure 4 is a fragmentary perspective view of an indicating unit ;

Figure 5 is a fragmentary perspective view of an automatic control unit ; and

Figure 6 is a perspective view of a console in which the indicating unit and automatic control unit are housed.

As shown in Figures 1 and 2, the axis, indicated at 10, of the wind tunnel 11 is horizontal and the two struts 12, 13 are movable vertically in a direction at right-

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angles to the axis of the tunnel. The model 14 is supported from the struts by means of a known form of strain gauge balance 15 in which the "sting" 16 of the model, having the respective strain gauges (not shown) attached to it, can be rotated about its longitudinal axis, as by means of an electric motor housed within the casing of the balance and driving the sting through a reduction gear.

This allows of rolling the model 14 through any angle from, say, 0° to 180°. By rolling the model through 90°, it may be "yawed" relatively to the air stream by changing the "incidence" of the balance—the model incidence in this case being zero. Any combination of model incidence and yaw may therefore be achieved by a combination of balance incidence and roll.

The two struts 12, 13 are flat ones mounted on vertical slide-bars 18*a*—18*d*, each strut having an electric motor 19, 20 driving lead screws 21*a*—21*d* through reduction gearing. The struts may be driven up or down, together or independently. Holes in the top of each strut take fulcrum pins 22 to form the attachment to the strain gauge balance which also has two holes, the rear one 23 being elongated. By sliding one strut relative to the other, the balance and model may be inclined at incidence.

The strut assembly, complete with slide bars and motors, is mounted in a frame 25 having rollers 26 which run in two parallel channels 27. The frame is traversed longitudinally in the channels by means of an electric motor 28 coupled to lead screws 29 through reduction gear 30. The channels are attached to the sides of a box which forms part of the tunnel shell and which is sealed from atmosphere. All electrical connections to the box are brought through pressurised plugs and sockets.

A straight potentiometer 32 (Figures 1, 2 and 3) is mounted on the strut 12 with the wiper 33 on the strut 13, with the result that the resistance ratio changes with incidence, i.e., when one strut is raised or lowered relative to the other. Coupled to this potentiometer is a master potentiometer 35 located outside the tunnel. When the resistance ratios of the two potentiometers differ, there is a resultant out-of-balance current which is amplified, as indicated at 36 in Figure 3, and arranged to operate relays 37 controlling the rear strut driving motor. This forms a servo control enabling any incidence angle to be set on a calibrated scale, indicated at 38, attached to the master potentiometer, thus switching the rear strut motor in the correct direction to restore balance. When a state of balance is reached (i.e., when the strut fulcrum pins are inclined at the angle set on the controlling potentiometer), the rear strut motor is automatically stopped. To minimise "hunting" about the position of balance, the motor armature is short-circuited and the field separately energised, when the motor is switched off, so as to provide dynamic braking due to the back E.M.F. generated.

Incidence is therefore controlled by the rear strut motor alone causing the rear strut to move relative to the front strut. The height of the model in the tunnel is varied by moving the front strut up or down as required, and, due to the potentiometer servo, the rear strut follows the front, maintaining the set angle of incidence.

An indicator unit 40 (Figure 4) has two scales 41, 42, one of which, 41, indicates the angle of incidence, and the other, 42, the height of the front strut fulcrum pin. It is operated by two repeater motors 43, 44 driven by transmitters 45, 46 (Figure 3) incorporated in the strut gear trains forming, in effect, two flexible drives from the strut lead screws to the indicator.

The rear strut repeater motor 44, and suitable reduction gear 48, are mounted in a drum 49 which can be rotated by the front strut repeater 43. When both struts are being raised or lowered together, the shaft connected to the rear strut repeater 44 rotates, relative to the drum, at the same speed as the drum is rotated by the front strut repeater 43. The directions of rotation are opposite, with the result that the two movements cancel each other out, and no change of incidence is indicated. When relative movement between the struts occurs, one repeater motor gains or loses speed on the other and a change of incidence is indicated, proportional to the change of relative height between the two strut fulcrums. The indicator scale 41 is non-linear and is graduated proportionally to the tangent of the true angle of incidence.

The front strut repeater 43, in addition to driving the drum 49, also drives the second scale 42 through suitable gearing 50. This scale gives a reading of the height of the front strut fulcrum pin relative to the tunnel centre line.

A transmitter 52 is incorporated in the gear train driving the incidence scale, which is used to drive a repeater in one channel of a printing recorder, and also the incidence simulator in the control mechanism (see below).

When the angle of incidence is changed by raising or lowering the rear strut only, the model moves in an arc about the front strut fulcrum pin. In order to restore the model to its original position (but with the new incidence setting) it is necessary to make vertical and horizontal adjustments to the two strut positions. It is the function of the control unit shown in Figure 5 to make these adjustments automatically.

This control unit includes a metal strip 56

similar in geometry to the strain gauge balance (but $\frac{1}{4}$ full size or thereabouts) and having a plain hole 57 and a slotted hole 58 corresponding to the plain and slotted holes in the balance 24 and 23, the unit being mounted on a panel 59. The pivot point 60 corresponding to the front strut fulcrum is fixed to the panel, and the rear one 61 may be traversed by means of a repeater motor and gearing 62, the motor being driven by the transmitter 52 in the incidence indicator gear train.

The metal strip 56 is thus arranged to maintain the same angle of incidence as the model and balance. A steel pin 65 located in one of a series of holes 66 in the metal strip engages with two slotted levers 69, 67 at right-angles to each other. Each of the levers has a pair of limit switches 70*a*, 70*b*, 71*a*, 71*b*, which operate relays (not shown) supplying power to the front strut and longitudinal traverse driving motors. When either lever is deflected from its central position (i.e., when the model moves vertically or horizontally due to a change in incidence), one of the limit switches is closed, which operates the driving motor in the direction necessary to return the predetermined point of the model to its correct position. The two lever and limit switch assemblies are mounted on carriages 72, 73 which are traversed along bars 72*a*, 73*a*, by means of repeater motors 74, 75 driven from transmitters 45, 83 in the front strut and horizontal traverse lead screw gear trains. The levers are thus returned to their central positions by the traversing action of the repeater motors, the limit switches then open, and the system comes to rest.

The locus of the front strut fulcrum is therefore an approximate arc having its centre at a point determined by the location of the operating pin 65 on the metal strip. By varying the position of the pin in the control unit, the virtual centre of the incidence mechanism may be positioned at any point on the fore and aft axis of the model.

The controls are mounted in a console, 78, shown in Figure 6, remote from the tunnel working section. The master potentiometer, the amplifier unit and the rear strut motor operating relays, are housed in a box 79 within the console, with the potentiometer control knob 80 and its calibrated scale 33 on the front panel. A similar box houses the indicator unit with its two dials 41, 42 indicating true incidence and front fulcrum height. The control unit is also mounted in the console together with a counter 82 driven by a repeater motor 83 from the transmitter in the horizontal traverse gear train. This unit gives the fore-and-aft location of the strut assembly in linear measure.

Three switches 86, 84, 85 control the front strut, rear strut, and horizontal traverse driving motors respectively. The switches each have three positions: the central are designated "Auto" and the other two "Manual Up" and Manual Down." The manual controls are used when it is desired to move the position of the virtual centre of the mechanism, or in the event of a fault in the servo or control unit.

The control unit corrects only for changes in the vertical or horizontal position of the model due to changes in incidence, and it is therefore necessary to isolate the relevant repeater motor in the unit, when the switches are in either of the "Manual" positions. The switches are therefore arranged to do this in addition to switching the driving motors.

What we claim is:—

1. Apparatus for supporting an aircraft model or the like in a wind tunnel so that its aero-dynamic characteristics may be analysed, including, in combination with the aircraft model or the like, two relatively-movable struts which extend into the wind tunnel and are arranged to be respectively moved, by means external of the wind tunnel, in a direction at right-angles to the wind tunnel axis, either in unison or independently, and also in unison along the wind tunnel, the struts supporting the model through the intermediary of means for rotating the model about its axis.

2. Apparatus for supporting an aircraft model or the like in a wind tunnel so that its aero-dynamic characteristics may be analysed, including, in combination with the aircraft model or the like, two struts which are relatively-movable by respective drive means in a direction at right-angles to the wind tunnel axis, the struts being movable in unison along the wind tunnel axis by a further drive means, each of the drive means being controlled by a remote control in which the respective movements of the struts are integrated to maintain a selected point of the model in a selected position irrespective of any change of attitude of the model, the struts supporting the model through the intermediary of a means for rotating the model about its axis.

3. Apparatus, according to Claim 2, in which the respective drive means are coupled to transmitters controlling repeater motors at a remote point, the repeater motors being connected to a differential gearing the output of which is used to drive an indicator, whereby the incidence of the model can be indicated at the remote point.

4. Apparatus, according to Claim 3, in which the output of the differential gearing drives a transmitter coupled to a repeater motor of the remote control, the repeater motor acting on a member, of similar geometry to the means supporting the model from the struts, to maintain it at the same angle of incidence as the model and the said

support, the member acting on a servo-mechanism controlling the position of the struts at right angles to the wind tunnel axis and on a servo-mechanism controlling the position of the struts longitudinally of the wind tunnel, to maintain the selected point of the model in the selected position.

5. Apparatus, according to Claim 4, in which the member carries a pin which is received in slots of levers at rightangles to each other, each lever having a pair of limit switches which operate relays supplying power to the front strut and said further drive means, whereby, when either lever is deflected from its central position, due to movement of the said member as a consequence of a change of incidence of the model, at least one of the limit switches is closed to operate the associated drive means in a direction necessary to return the selected point of the model to its correct position, the respective levers and their associated limit switches being mounted on carriages which are traversed by a repeater motor coupled to a transmitter of the said associated drive means to follow up the struts, and, when the selected point of the model is in its correct position, to restore the lever to a position in which the said limit switch is no longer operated.

6. An apparatus for mounting an aircraft or the like in a wind tunnel, substantially as hereinbefore described with reference to the accompanying drawings.

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PROVISIONAL SPECIFICATION.

Supporting Model Aircraft or the like in a Wind Tunnel.

We, SIR W. G. ARMSTRONG WHITWORTH AIRCRAFT LIMITED, a British Company, of Baginton, Near Coventry, Warwickshire, do hereby declare this invention to be described in the following statement:—

This invention relates to the supporting of an aircraft model or the like in a wind tunnel so that its aero-dynamic characteristics may be analysed, and the invention is particularly concerned with a support by which the angles of incidence, roll and yaw of the model can be remotely controlled.

It is important when testing such a model in a wind tunnel containing dry air that the tunnel should not have to be opened for adjustment of position of the model, and for this reason the attitude of the model should be remotely controlled.

It is also essential that the model, in any adjusted position, should be in a region of the tunnel which is free from air disturbances such as may be caused by small irregularities of the tunnel walls—particularly when the model is being tested with air travelling at supersonic speeds, as, in these conditions, shock waves can be formed within the tunnel.

One object of the invention is to provide an improved support by which the angles of incidence, roll and yaw can be remotely controlled, and by which the model can be maintained within a region of the tunnel which is free from disturbances.

A further object is to provide a support by which, when the attitude of the model is to be varied, a given point of the model can be maintained in a predetermined position.

The invention involves the combination with an aircraft model or the like, of two relatively-movable struts, which extend into the wind tunnel and are arranged to be respectively moved, by means external of the wind tunnel, in a direction at right-angles to the wind tunnel axis, either in unison or independently, and also in unison along the wind tunnel, the struts supporting the model through the intermediary of means for rotating the model about its axis.

The invention also involves the combination with an aircraft model or the like, of two struts which are relatively-movable by respective drive means in a direction at right-angles to the wind tunnel axis, the struts being movable in unison along the wind tunnel axis by a further drive means, each of the drive means being controlled by a remote control in which the respective movements of the struts are integrated to maintain a selected point of the model in a selected position irrespective of any change of attitude of the model, the struts supporting the model through the intermediary of a means for rotating the model about its axis.

In one construction according to the invention, in which the axis of the wind tunnel is horizontal and the two struts are movable vertically in a direction at right-angles to the axis to the tunnel, the model is supported from the struts by means of a known form of strain gauge balance in which the "sting" of the model, having the respective strain gauges attached to it, can be rotated about its longitudinal axis, as by means of an electric motor driving through a gear box.

This allows of rolling the model through any angle from, say 0° to 180°. By rolling the model through 90°, it may be "yawed" relatively to the air stream by changing the

"incidence" of the balance—the model incidence in this case being zero. Any combination of model incidence and yaw may therefore be achieved by a combination of balance incidence and roll.

The two struts are flat ones mounted on vertical slide bars, each having an electric motor driving a lead screw through reduction gearing. The struts may be driven up or down, together or independently. Holes in the top of each strut take fulcrum pins to form the attachment to the strain gauge balance which also has two holes, the rear one being elongated. By sliding one strut relative to the other, the balance and model may be inclined at incidence.

The strut assembly, complete with slide bars and motors, is mounted in a frame having four rollers which run in two parallel channels. The frame is traversed longitudinally in the channels by means of an electric motor coupled to lead screws and reduction gear. The channels are attached to the sides of a box which forms part of the tunnel shell and which is sealed from atmosphere. All electrical connections to the box are brought through pressurised plugs and sockets.

A straight potentiometer is mounted on one of the struts with the wiper on the other, with the result that the resistance ratio changes with incidence, i.e., when one strut is raised or lowered relative to the other. Coupled to this potentiometer is a master potentiometer located outside the tunnel. When the resistance ratios of the two potentiometers differ, there is a resultant out-of-balance current which is amplified and arranged to operate relays controlling the rear strut driving motor. This forms a servo control enabling any incidence angle to be set on a calibrated scale attached to the master potentiometer, thus switching the rear strut motor in the correct direction to restore balance. When a state of balance is reached (i.e., when the strut fulcrum pins are inclined at the angle set on the controlling potentiometer), the rear strut motor is automatically stopped. To minimise "hunting" about the position of balance, the motor armature is short-circuited and the field separately energised, when the motor is switched off, so as to provide dynamic braking due to the back E.M.F. generated.

Incidence is therefore controlled by the rear strut motor alone causing the rear strut to move relative to the front strut. The height of the model in the tunnel is varied by moving the front strut up or down as required, and, due to the potentiometer servo, the rear strut follows the front, maintaining the set angle of incidence.

An indicator unit has two scales, one of which indicates the angle of incidence, and the other, the height of the front strut fulcrum pin. It is operated by two repeater motors driven by transmitters incorporated in the strut gear trains forming, in effect, two flexible drives from the strut lead screws to the indicator.

The rear strut repeater motor, and suitable reduction gear, are mounted in a drum which can be rotated by the front strut repeater. When both struts are being raised or lowered together, the shaft connected to the rear strut repeater rotates, relative to the drum, at the same speed as the drum is rotated, relative to earth, by the front strut repeater. The directions of rotation are opposite, with the result that the two movements cancel each other out, and no change of incidence is indicated. When relative movement between the struts occurs, one repeater motor gains or loses speed on the other and a change of incidence is indicated, proportional to the change of relative height between the two strut fulcrums. The indicator scale is non-linear and is graduated proportionally to the tangent of the true angle of incidence.

The front strut repeater, in addition to driving the drum housing the rear strut repeater, also drives the second scale, through suitable gearing. This scale gives a reading of the height of the front strut fulcrum pin relative to the tunnel centre line.

A transmitter is incorporated in the gear train driving the incidence scale, which is used to drive a repeater in one channel of a printing recorder, and also the incidence simulator in the control mechanism (see below).

When the angle of incidence is changed by raising or lowering the rear strut only, the model moves in an arc about the front strut fulcrum pin. In order to restore the model to its original position (but with the new incidence setting), it is necessary to make vertical and horizontal adjustments to the two strut positions. It is the function of a control unit to make these adjustments automatically.

This control unit includes a metal strip similar in geometry to the strain gauge balance (but ½ full size or thereabouts) and having a plain and slotted hole corresponding to the strut fulcrums, the unit being mounted on a panel. The pivot point corresponding to the front strut fulcrum is fixed to the panel, and the rear one may be traversed by means of a repeater motor and gearing, the motor being driven by the transmitter in the incidence indicator gear train.

The metal strip is thus arranged to maintain the same angle of incidence as the model and balance. A steel pin located in one of a series of holes in the metal strip engages with two slotted levers at right angles to each other. Each of the levers has a pair of limit switches, which operate relays supplying power to the front strut and longitudinal traverse driving motors. When either lever is

deflected from its central position (i.e., when the model moves vertically or horizontally due to a change in incidence), one of the limit switches is closed, which operates the driving motor in the direction necessary to return the model to its correct position. The two lever and limit switch assemblies are mounted on slide bars and are traversed along these bars by means of repeater motors driven from transmitters in the front strut and horizontal traverse lead screw gear trains. The levers are thus returned to their central positions by the traversing action of the repeater motors, the limit switches then open, and the system comes to rest.

The locus of the front strut fulcrum is therefore an approximate arc having its centre at a point determined by the location of the operating pin on the metal strip. By varying the position of the pin in the control unit, the virtual centre of the incidence mechanism may be positioned at any point on the fore and aft axis of the model.

The controls are mounted in a console, remote from the tunnel working section. The master potentiometer, the amplifier unit and the rear strut motor operating relays, are housed in a box within the console, with the potentiometer control knob and its calibrated scale on the front panel. A similar box houses the indicator unit with its two dials indicating true incidence and front strut fulcrum height. The control unit is also mounted in the console together with a counter driven by a repeater motor from the transmitter in the horizontal traverse gear train. This unit gives the fore and aft location of the strut assembly in linear measure.

Three switches control the front strut, rear strut, and horizontal traverse driving motors. The switches each have three positions: the central are designated "Auto" and the other two "Manual Up" and "Manual Down." The manual controls are used when it is desired to move the position of the virtual centre of the mechanism, or in the event of a fault in the servo or control unit.

The control unit corrects only for changes in the vertical or horizontal position of the model due to changes in incidence, and it is therefore necessary to isolate the relevant repeater motor in the unit, when the switches are in either of the "Manual" positions. The switches are therefore arranged to do this in addition to switching the driving motors.

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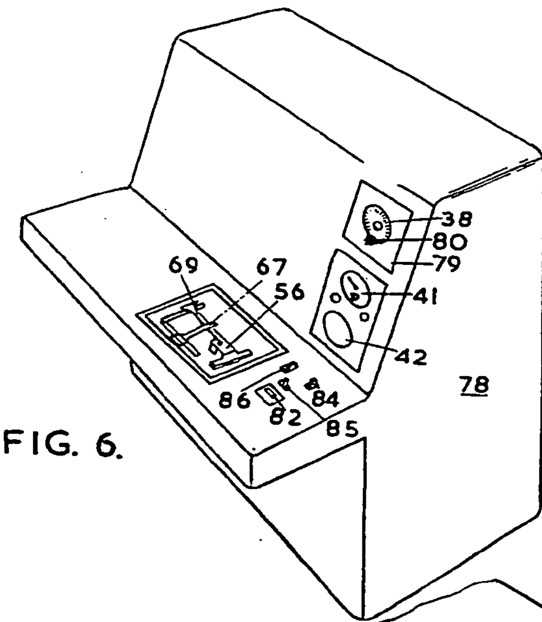
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FIG. 6.

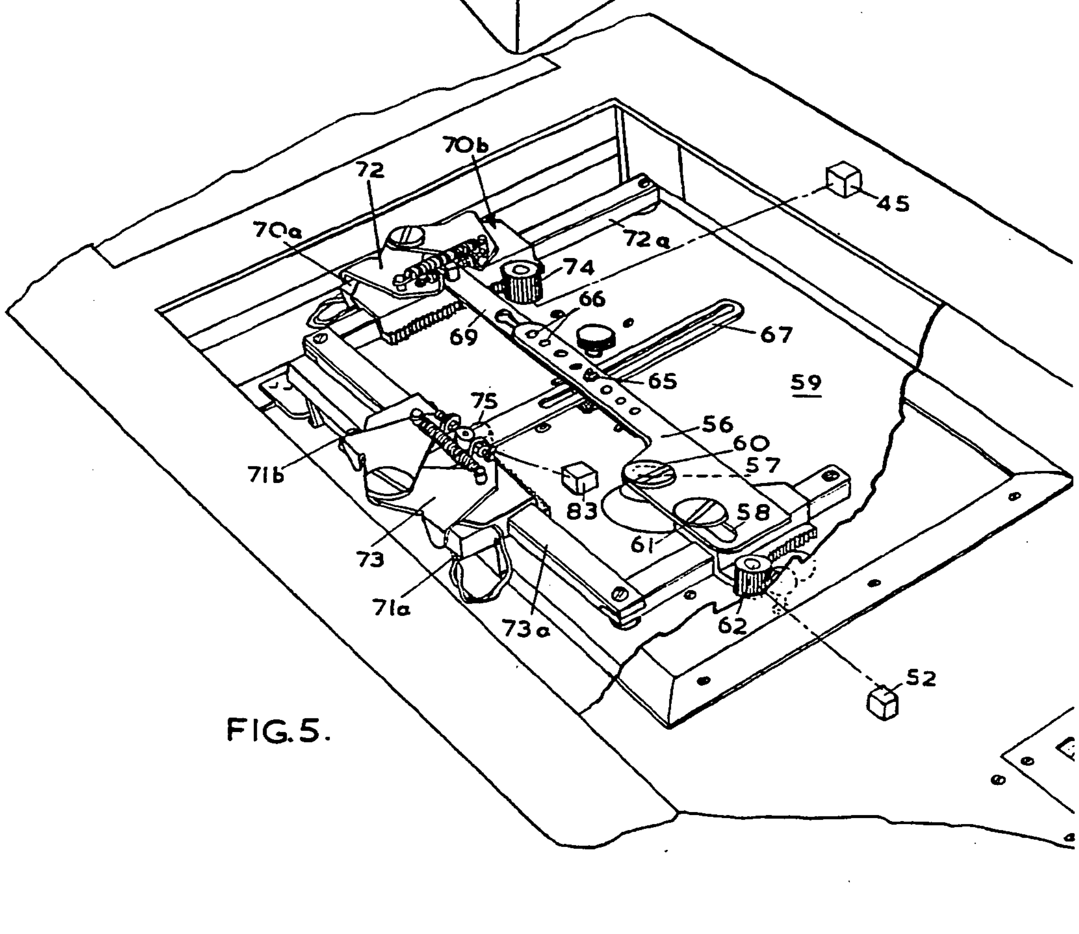
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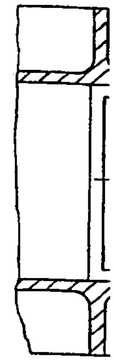
FIG. 5.



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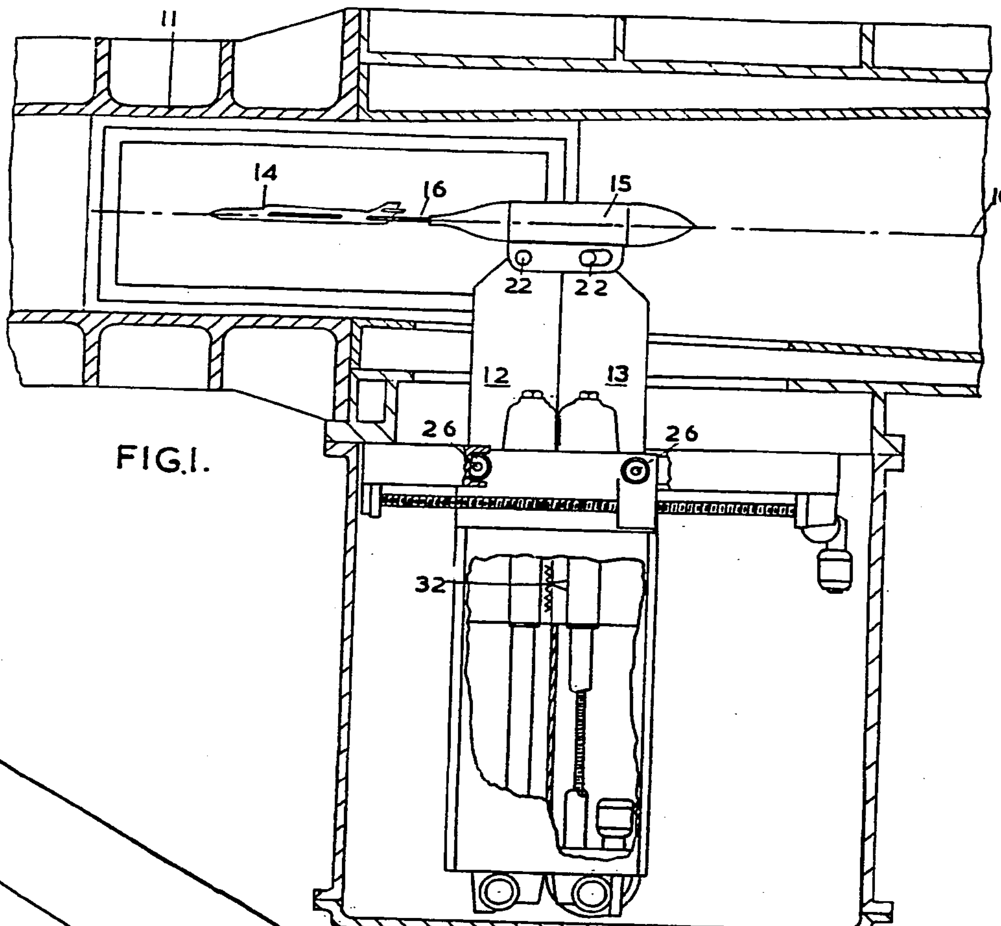
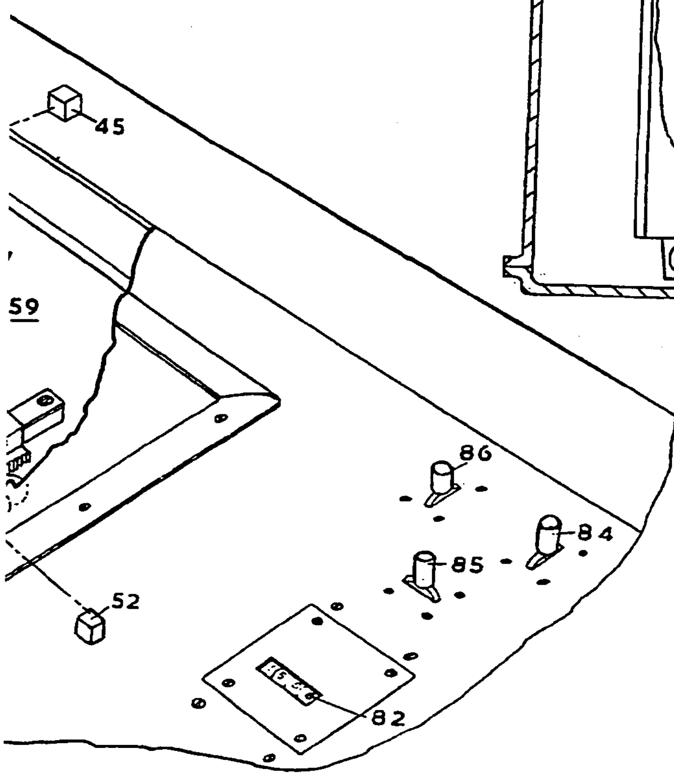


FIG.1.



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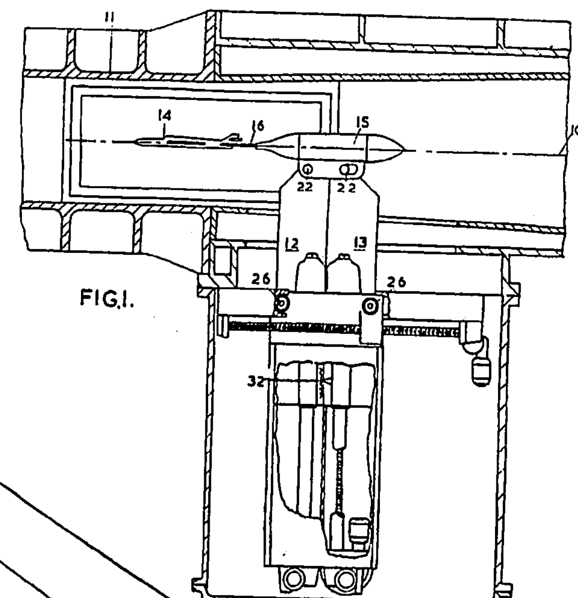

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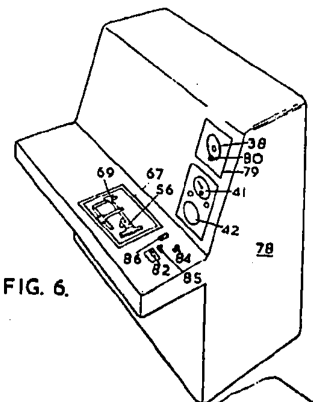

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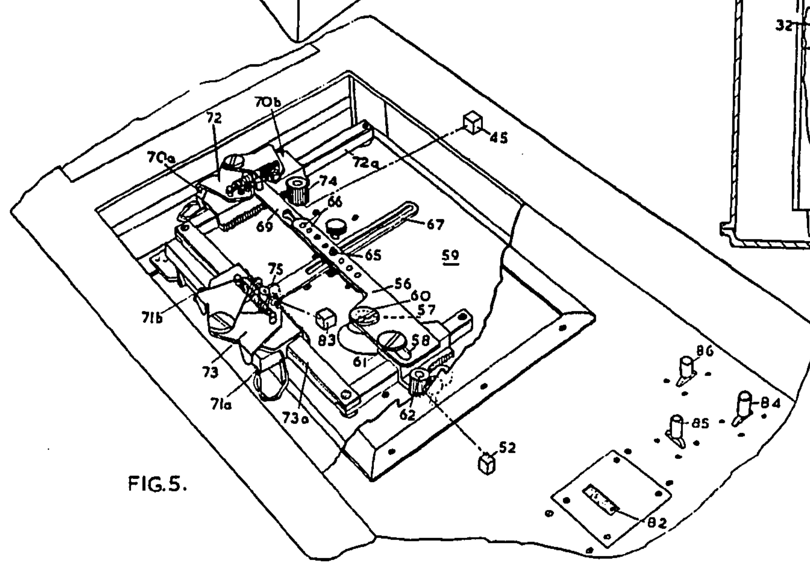

FIG.5.

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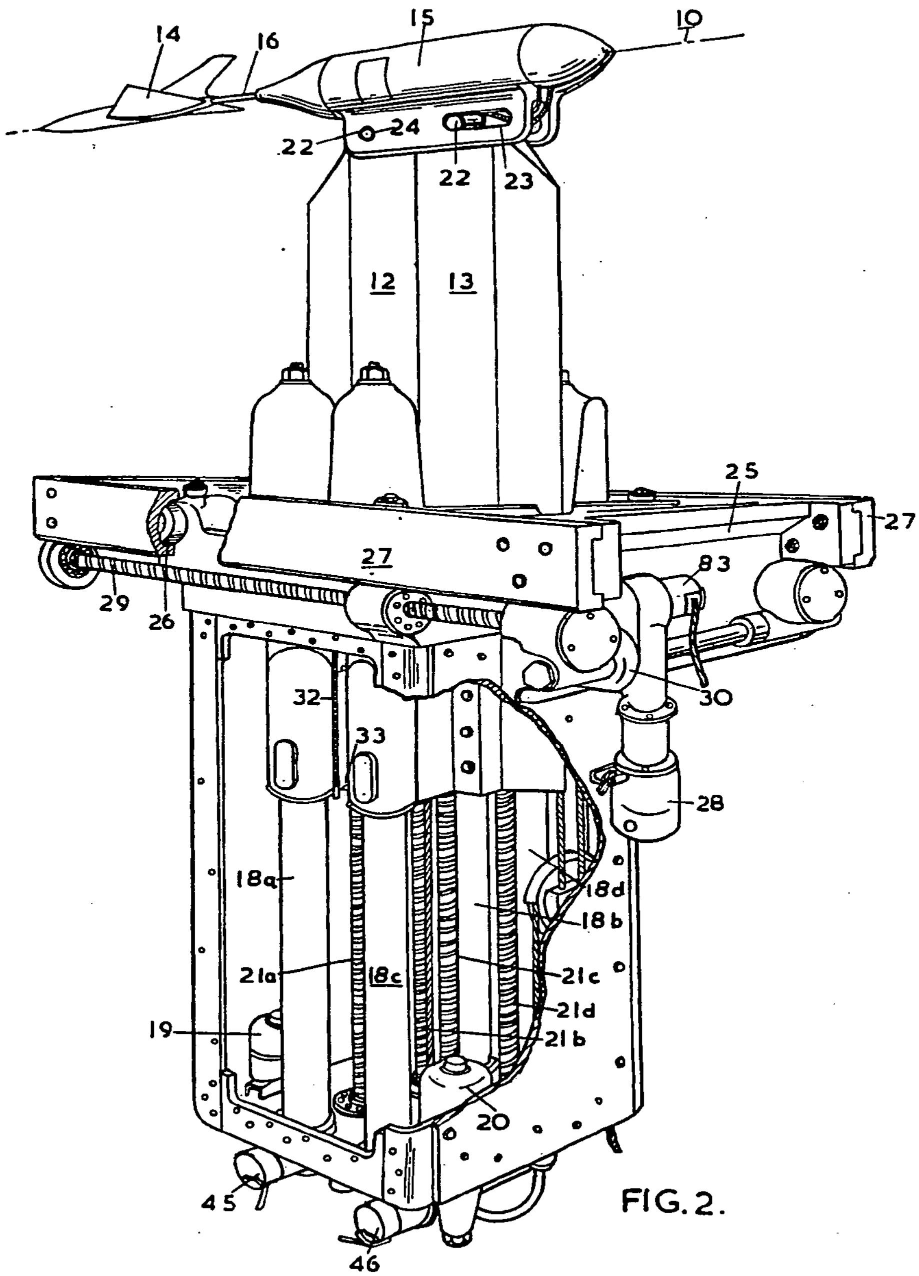
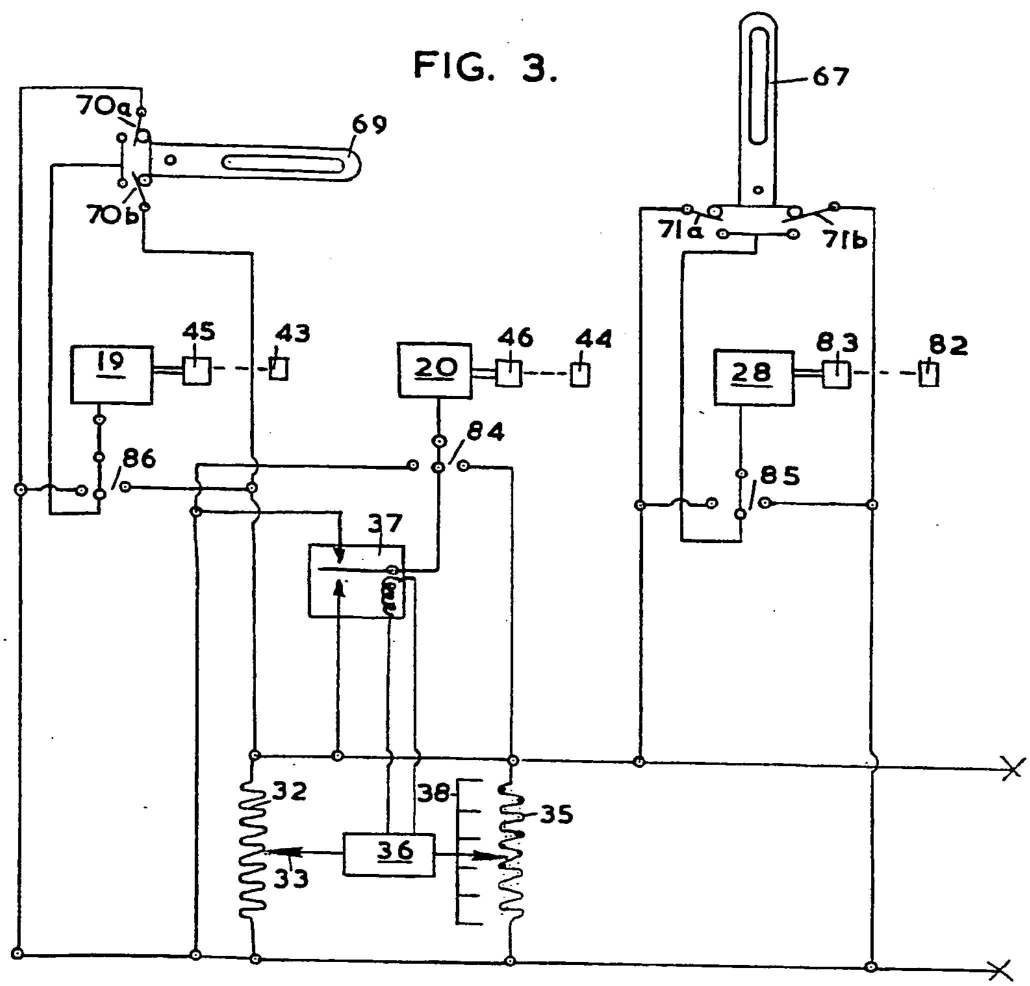


FIG. 2.

FIG. 3.



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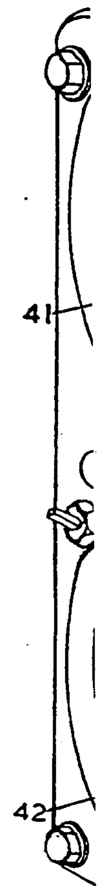

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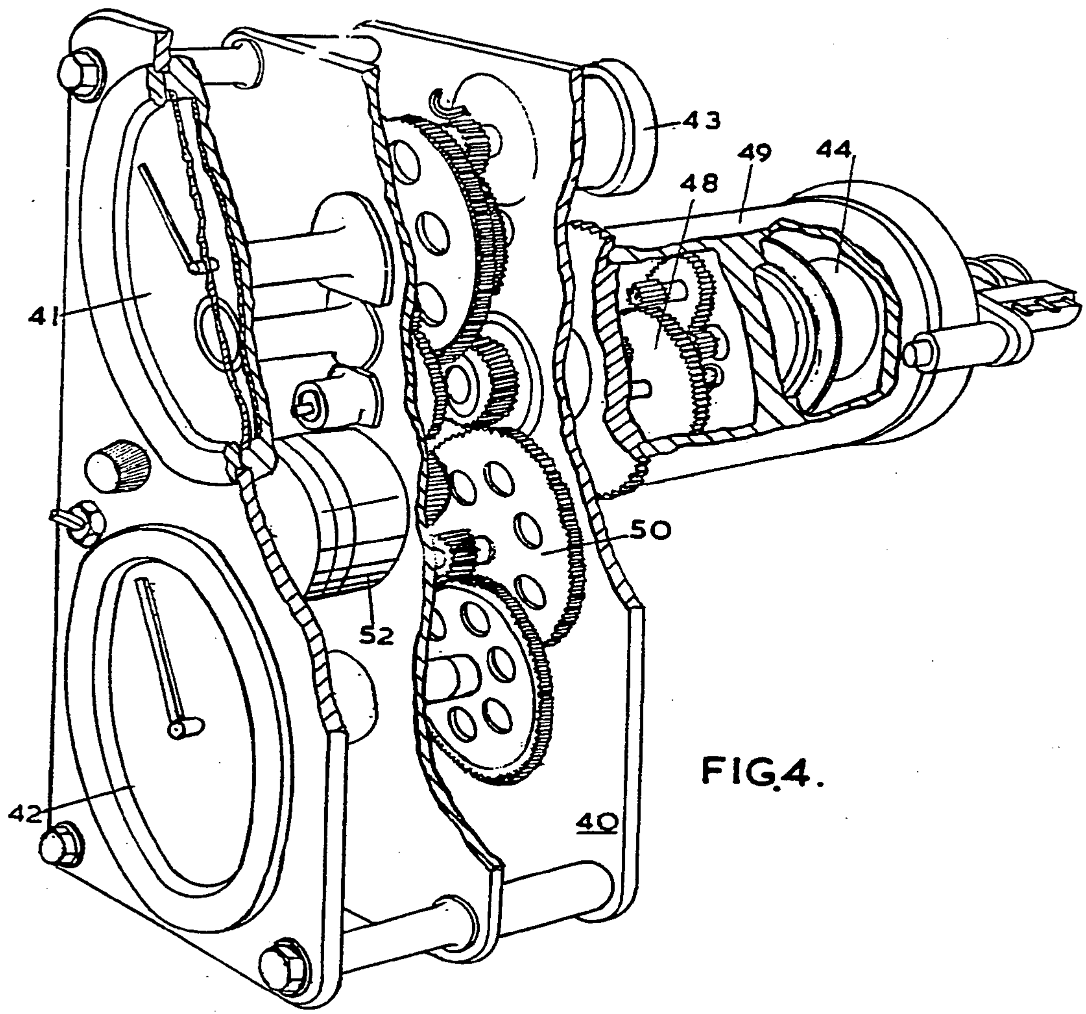

FIG.4.

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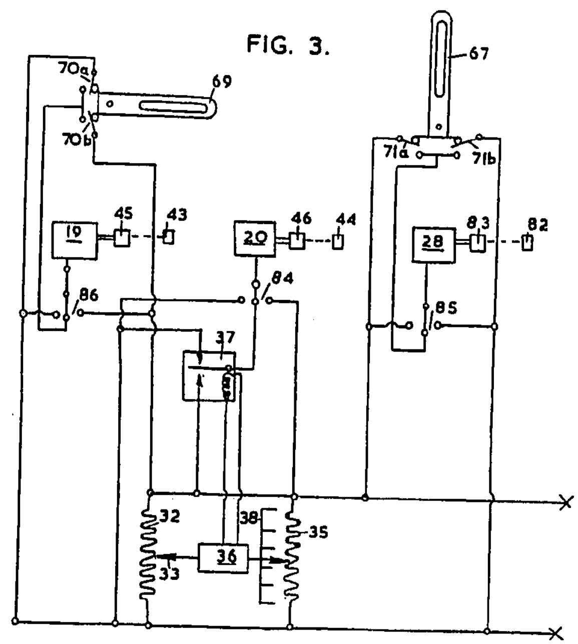
FIG. 3.



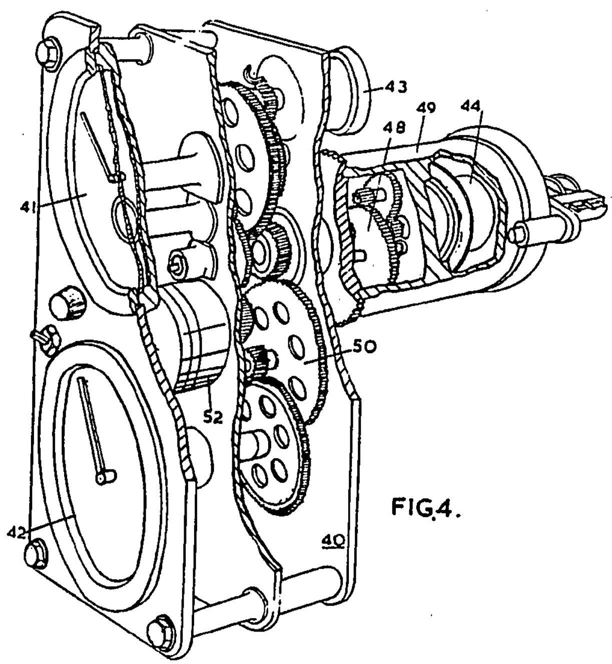


FIG.4.